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EARTH ROADS

By

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PREFACE

The object of this book is to present as thoroughly as possible, yet concisely and simply, the elementary principles of the construction and maintenance of earth roads and to set forth the salient features of good practice in this work.

The term "earth roads" as used includes also sand-clay and burnt-clay roads, which are properly to be considered in that classification. Roads of this character at present constitute the large majority of all roads in the country, and this condition must necessarily obtain for many years to come. Earth roads are the roads over which must be hauled most of the country's food supply and they are the roads upon which a considerable proportion of the rural population of the country depends for its travel between communities and between the farm and the business, educational, social and religious centers. In addition, the earth road is the road upon which perhaps the greatest return can be secured by the outlay of comparatively small sums for improvement.

For these reasons, the earth road is of the utmost economic importance and its improvement a matter which lies very close to the welfare of the country. If this book shall serve to bring about the employment of better methods in the improvement and upkeep of these roads it will have served a useful purpose; and in the hope that it may do so it is offered to those who are identified with or interested in the great work of highway betterment.

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EARTH ROADS

GENERAL CONSIDERATIONS

While it may not be so apparent to the ordinary man, the engineer will hardly deny that so far as the United States is concerned, earth roads occupy a most important and unique position in the domain of highway engineering. The principal reason lies in the fact that of the 2,210,857 miles of roads in this country, only 187,910 miles, or about 8½ per cent., according to the 1911 report of the U. S. Office of Public Roads, may be termed improved roads.

The bearing of this condition in general, and its economic effect in particular, are nowhere better stated than in the forceful words of James J. Hill, whom we quote as follows:

> The enormous volume of commodities that finds either its origin or its final destination on the farm or in the village must be transported over the dirt road and pay toll to the obstructions which that offers to traffic.
>
> Good roads are expensive, but it costs more money to do without them than to build them. The attempt to improve the highways by the old system of local supervision, small appropriations, taxes worked out instead of paid in cash, and petty political control, wastes every dollar so expended.*

Most earth roads, of necessity, are but temporary in character and merely the forerunners of improved ones, but it must be many years before even a small percentage of the more than 2,000,000 miles of rural highways can receive a better surfacing, and in the meanwhile the earth road must do duty as it is. The problem is, therefore, how to secure the best results from these roads, as they are, with the least expenditure of money.

In general, the same rules and principles of location, drainage, grade, cross section, construction, maintenance and repair, apply to them as to the most modern type of highway, and it is only by the application of these principles that improvements may be expected which will be of lasting benefit.

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*South Dakota Good Roads Convention, Aberdeen, South Dakota, October 26-7, 1910.

The work of building and maintaining dirt roads, it should be understood, requires the special study of each particular case, and it cannot be urged too strongly that those with special skill should, in like manner, be employed to solve these engineering problems.

It is the purpose here, therefore, to present briefly the principles which underlie the economical construction, maintenance and repair of dirt roads, and to outline the methods which have come to be recognized as those most likely to accomplish the best results.

If we begin by attempting to trace the development of rural highways in the United States, we find that the growth of the country has been so rapid that the highways have failed to keep pace with it, and the original routes, located with no idea to the future and no thought of engineering principles, are still made to do service in spite of their many defects.

The controlling motive in the selection of these older highways was that of distance, regardless of grade, drainage, etc.; and, in a like manner, the West is rolling up a heavy burden against the future by the fact that the common road follows the section lines rather than directions securing easy grade and good drainage. This is due to the rectangular method of subdividing the public lands of the United States.

Let us consider briefly the work that the more progressive states are now undertaking in connection with the betterment of their highways. It is in a large measure concerned with the improvement of surfacings of main thoroughfares, but that, certainly, is not all. A very large part involves the application of the principles of good road building to the rural highway, such as the removal of summits and the filling in of hollows to reduce the grade, the elimination of dangerous curves, the drainage of low spots, and the diversion of water in general from the highway. Are not the different road commissions proving that it is easier to go round a hill than over it, and perhaps no longer? In general, are they not trying now to correct the mistakes inherited from the past? Let us see how these may be avoided in the future by considering the more important factors bearing on the subject, the first of which is location.

ROAD LOCATION

In its broadest sense, road location has for its object the collection of information along a proposed route, that a highway may be built which will show the least cost in construction, maintenance and transportation, in keeping with the needs of the traffic using it.

Nowhere may money be expended to better advantage, as is evident if we consider the many cases where expensive changes are now being made in the endeavor to correct errors that exist in the line, grade and drainage in some of our highways. All that may be said with reference to the location of a new road applies equally well in relocation work. There is, of course, less occasion today for the former, but many instances arise where relocations for at least short stretches are absolutely necessary.

Where a straighter line or a lower grade may be had, under circumstances that the cost of construction and of maintenance warrant, or where the maximum grade cannot be reduced except at great expense, a new location may be advisable. The ruling grade, that is, the greatest grade, on the road should then be discarded and a new and lower one, but one not to exceed 7 per cent. and preferably 5 per cent., substituted. By per cent. of grade is meant the number of feet rise in 100 ft. of distance. Thus a one per cent. grade would mean that in a distance of 100 ft. the road had a rise of 1 ft.

The same care observed in locating a railroad line should be exercised in respect to those features that apply to a highway, and the work may be considered under the following heads, in the order named: Reconnoissance, or preliminary examination of the district; Preliminary Survey; Final Survey, and Estimates.

Reconnoissance.—The reconnoissance proper consists of a careful preliminary examination of the country between the points to be connected.

Preliminary Survey.—In the preliminary survey a line is staked out on the ground by means of an engineer's transit, which follows in a general way the direction of the reconnoissance. Distances are measured with a tape and angles are read. According to the practice in New York state, the notes contain, among other things, bench marks, azimuths, magnetic bearings, etc.; the distance between benches not exceeding 1,000 ft., and elevations being checked to within .01 ft.; measurements from the center line to all fences, buildings, shade trees, houses, barns, etc, are taken, while roads or fences that cross this line are noted with their magnetic bearings; adjacent property is indicated by the name of the owner, and bridges are sketched in as well as being located; a record is kept of the soil, rock outcrops, field stone, quarries, gravel pits, etc.

The location that is thus established is gone over with a level so that a profile of the center line may be obtained, and at the same time topography is taken at both sides in order that information may be secured to aid in an intelligent shifting of the proposed road to the right or left if it be found necessary

Elevations should be referred to some known height above sea level and check levels run wherever possible. Slopes beyond the right of way may usually be merely indicated.

When all this information has been placed on a map, it gives a plan of the center line, with the country adjacent, and a profile which shows the irregularities of the ground. The plan is made use of in adjusting the direction of the route to the country, while the profile aids in determining the grade.

With these data it is easy to draw on paper a final line conforming to the desired grade, curvature, and other ruling features, and after this it then becomes merely a matter of transferring to the ground the line that has been placed on the paper.

Final Survey.—This transfer is accomplished by setting stakes in the ground every hundred feet on straight lines and putting in curves with the transit, while elevations are taken at these stakes for a new profile and for cross sections.

The latter must be taken over culverts and at streams if any are crossed, and a profile to the right and left must also be made. With the amount of "cut and fill" at each station recorded in the note book, it is not difficult to place the shoulder and grade stakes at the sides, but as this involves the entire question of cross sectioning, it will not be discussed here.

Estimates.—It is customary after all these data have been collected to make an estimate of the cost of construction which is usually subdivided into various heads, such as the cost of, "cut and fill," "bridges," "culverts," etc., etc. Such estimates are presented on standard forms used for the purpose, and an allowance of about 10 per cent. is added to each item to cover discrepancies.

To arrive at an exact idea of the cost of construction, which in the end is the most important thing in any undertaking, such data as outlined above are absolutely essential, though it is true they will generally be in less detail. But aside from cost, it is equally important to have some idea of the nature and amount of traffic and the interests involved in the use of the proposed route.

COST AS AFFECTED BY LOCATION

If we consider location apart from everything else, that road will cost the least where there is the least grading or construction work to be done. While this will reduce the item of "cost of construction," it is evident it may unduly increase both the "cost of transportation" and "cost of maintenance." Suppose, on the other hand, it were desirable, irrespective of dollars and cents, to make the "cost of transportation" a minimum; it would mean the elimination of both grades and curves, but in accomplishing this the "cost of construction" would probably be increased beyond all reason.

With the former condition existing the "cost of maintenance" would necessarily be high, while with the latter it might vary between a very high figure and a very low one. To reduce the "cost of construction," therefore, we need but to avoid doing certain things that ought to be done; but to reduce the "cost of transportation" we must make the line as short, and straight, and level, and well drained as possible.

It is plain that the shorter a road is, other things being equal, the cheaper it will be to haul over it. Too often, however, the statement "other things being equal" has been lost sight of, the aim having been to reduce distance as referred to a horizontal plane, forgetful of the fact that distance may be measured up and down as well; and thus today many a hill is climbed to secure directness, whereas a slight detour might have avoided the grade and not increased the length.

Though not such an important factor as grade, curvature is receiving more consideration every year with the increased use of the automobile. Merely as a protective feature, therefore, "hairpin turns" and other similar short reverse curves in which the view of approaching vehicles is obstructed should be carefully avoided.

TRACTION

Since the problem in the construction of most grades is an economic one—that is, how the greatest load may be hauled with the least effort, which means money—it will be proper to consider those factors which tend to reduce the load a team may haul.

The force exerted by a team is called the tractive force, and may be measured in pounds pull on a spring balance or scales placed between the whiffletree and the wagon. It is customary to state this as the pounds pull per ton of load, the load including all behind the balance. This tractive force overcomes tractive resistances, which are in general divided under three heads: (1) axle friction, (2) rolling resistance, and (3) grade; and the more we decrease these, the greater will be the load we can haul.

Not much is known concerning axle friction in wagon haulage, but at best it is of small importance. It depends upon the material of which the hub and axle are made, upon the amount of lubrication and the nature of the lubricant. With poor lubrication it may vary from two to six times the value obtained with good lubrication.

Rolling resistance is due principally to the fact that, no matter how perfect the road's surface, the wheel of a vehicle will sink to some extent into the material, and is thus always in the act of rolling up a small incline. It would be less, of course, in the case of the wheels of a locomotive on steel rails than in that of a cart hauled on a soft dirt road, but it exists in the former as well as the latter.

The various components of rolling resistance affecting its value are: (a) The diameter of the wheel; (b) the width of the tire; (c) the speed; (d) the presence or absence of springs, and (e) the road surface.

Experimentally it has been proven that the greater the diameter of a wheel, the less the rolling resistance. This may be accounted for by the fact that the smaller wheel makes a deeper impression in a road and, therefore, requires greater effort to haul it out.

Perhaps no one of the above mentioned components of rolling resistance has been discussed so much as width of tire, in its effect upon both haulage and road preservation. Generally the subject is approached from the standpoint of road preservation rather than that of decrease in tractive force; but both are worthy of careful consideration.

Narrow-tired wheels, like those of small diameter, are often required to carry a greater load than they should, with the consequent effect that they increase the pull upon the horse, and, by sinking deeper into the road, destroy it more quickly. In New Jersey the Highway Commission points out that when a road is improved, immediately heavier loads are hauled on the same tires, causing ruts which hold water, with the consequent breaking up of the foundation. Such ill effects can only be overcome by wider tires.

It has been proven that with wheels of equal diameter, a tire 2.4 ins. wide causes twice as much wear of a road as that produced by a tire 4.6 ins. wide; but it is questionable if tires broader than this are beneficial.

Tests made on dirt roads, in all conditions, and on meadow, pasture and ploughed land, both wet and dry, show the following results:

There are but three conditions under which broad tires draw heavier than narrow tires, namely (1) when the road is sloppy, muddy or sticky on the surface, and firm or hard underneath; (2) when the surface is covered with a very deep, loose dust and hard underneath; (3) when the mud is very deep and so sticky that it adheres to the wheels on both kinds of wagons. It appears also that the dust must be extraordinarily deep to show a higher draught from broad tires than from narrow tires. The three conditions just named, therefore, are somewhat unusual and of comparatively short duration.

Through a majority of days in the year, and at times when the dirt roads are most used, and when their use is most imperative, the broad-tired wagons pull lighter than the narrow-tired wagons.

Speed increases rolling resistance, but this is of such slight significance in the case of wagon haulage on dirt roads that it may be disregarded. In the case of automobile traffic it would prove a more important factor.

Springs decrease the shock to which the vehicle is subject in rolling over rough surfaces, thus diminishing the draught as well as wear and tear to wagon and road. Like speed, it is but a small factor in rolling resistance.

The effect of the condition of the road surface upon rolling resistance is evident in the two cases of a railway and a dirt road. It requires no argument with the statement that for the same energy, a much heavier load may be hauled on the former than on the latter. This proves that the smoother and harder the road surface, disregarding the question of foothold, the greater the load that may be hauled. Smoothness and hardness reduce tractive force, produce comfort, and diminish shock, wear and tear on road, vehicle and animal.

GRADES

Aside from the question of drainage, the ideal road should be as nearly level as possible, since under these conditions it favors the load neither going nor coming and presents less resistance to haulage.

In any case the ruling grade is that which limits the load that may be hauled over any section of a road, and hence it should always be the object to reduce such a grade to some lower percentage. Furthermore, a horse's power for hauling diminishes greatly going up a hill, since it is compelled to haul itself up as well as the load. It should be noted, however, that for short distances a horse is able to exert several times its usual force, and also that the smoother and harder the surface the poorer the foothold may be, in consequence of which the power that a horse may exert will be less.

This is shown by the following table taken from Baker, which gives the effect of grade upon the load a horse may draw, the load being in terms of the weight of the horse:

Grade per cent.	Earth Road		
	Best	Spongy	Muddy
0	3.00	2.00	1.00
1	2.09	1.50	0.91
2	1.51	1.14	0.67
3	1.11	0.87	0.54
5	0.60	0.50	0.33
6	0.43	0.36	0.25
7	0.29	0.25	0.18
8	0.18	0.15	0.11
9	0.08	0.07	0.05
10	0.00	0.00	0.00

SOIL CONDITIONS

In a great measure the kind of service that a dirt road may be expected to render depends upon the peculiarities of the soil found along the right of way, which, of necessity, is used in the construction of the highway itself. It may be well here, therefore, to classify those materials which are most frequently met with. They are clay, sand, gravel, loam, gumbo and hardpan, the name applied depending upon some distinctive characteristic which the soil possesses.

A clayey soil is one in which the particles composing it are extremely fine and which possesses the decided disadvantage of being very retentive of water. For this latter reason it is especially hard to drain and therefore particularly unsatisfactory for road building purposes.

Sandy soils or those with 80 per cent. or more of sand, while not especially good for road building, are porous in nature, holding little or no water. This is due to the fact that they are composed to a greater or less degree of sand grains which offer little resistance to the water in its passage through the ground. They possess little or no body, however, unless confined. All varieties of sandy soils exist, from those containing but a small proportion to those carrying over 90 per cent.

As the name would indicate, gravelly soils are ones in which pebbles and finer material are found, and which, in consequence, by making the soil more or less porous, afford good drainage.

Soil known as loam is the most desirable from the standpoint of the highway engineer, as it possesses neither the extreme porosity of sand, nor the retentive characteristic of clay. It would seem to combine some of the good qualities of each, for, like sandy soil, it may be readily drained, and, on the other hand, like clay, it is easily compacted.

All shades of difference are found in these soils so that the terms sandy loam, sandy clay, gravelly loam and gravelly clay, are frequently made use of to indicate such minor discrepancies.

Gumbo soils, which are found largely in the Mississippi River Valley, consist of loam mixed with enough clay to make them extremely sticky and unsatisfactory when used on a highway.

Hardpan, while not so frequently employed as a road material proper, is of such common occurrence that it may be mentioned here. It is usually found beneath the surface soil as a layer of more or less hard material. Speaking broadly, the term is applied to any hard clay which is found as a subsoil, while specifically the name is used to designate any soil in which the particles are being cemented together by means of water containing lime, iron or silica. The material varies in hardness from that which requires the use of powder or dynamite to remove to that which may be easily excavated with a pick and shovel.

DRAINAGE

Dirt roads are not ones where a great deal of money may be or usually is expended, but it is a fact that of those factors tending to make such roads fit for traffic or absolutely impassable, and, therefore, where money may be used to the greatest advantage, drainage is by far of most consequence. This is frequently referred to by the remark that the three most important things in road building and maintenance are: First, drainage; second drainage, and third, more drainage; and is recognized in practice by the fact that in the least developed roads, side ditches are generally provided to drain the subgrade and afford a waterway for that which, falling on the surface, drains toward them.

Drainage may be accomplished in three ways: First, surface drainage; second, subsurface drainage, and third, drainage through side ditches.

Surface drainage has for its object the directing of water falling upon the road toward the sides as quickly as possible so that none may be allowed to collect on the surface to form pools, produce mud, and gradually sink through to the subgrade unless it be evaporated by sun and wind, and it is secured by crowning the road and keeping the surface firm, hard and smooth.

By crowning is meant the elevation of the center of the roadway above the sides; the smoother the surface the less this need be. Where ruts and holes exist, proper surface drainage is impossible, except with high crowns; but this forces vehicles to the center, produces ruts and hollows by tracking, and creates steep shoulders, all of which is detrimental to good service.

The crown also depends upon the grade lengthwise of the road and the material of which the latter is constructed. Consequently, as earth is easily cut up, a much greater crown is required for a dirt road than for one with a smoother and harder surface.

For purposes of drainage, absolutely flat roads are to be discouraged, as all surface water would then have to be discharged to the ditches by means of the crown alone. On the other hand, the grade should never be so great as to allow water to flow in a torrent along the middle of the roadway and wash out gullies; or, if the grade *is* excessive, the crown must be correspondingly increased, within limits, to counteract this tendency and cause the water to move diagonally across the road toward the gutters.

Where a steep hill exists it is customary to construct shoulders, called "thank-you-mams," water breaks, or breakers, at intervals along the road, to divert water flowing down the center to the ditches at the sides. These are usually in the form of a shoulder of earth, or stone or logs covered with earth, set diagonally across the road, or else in the form of an obtuse angle with the apex in the center pointing up-hill. Though very generally used on rural roads they increase the grade and therefore the pull on a horse, and on this account are objectionable. But on the other hand, they afford a resting place. Where they join the side ditches it should not be too abruptly, as they then tend to scour the gutter banks. A better plan would be to have turnouts at the side to rest the horses, and to pave the gutters to prevent undue washing.

In depressions, surface catch waters are necessary to carry to the side ditches water which may have flowed down the road to the low spot. These differ from the foregoing in that they are shallow trenches (to prevent jolting), crossing the road at right angles, and having the bottom paved with gravel, cobble, or field stone.

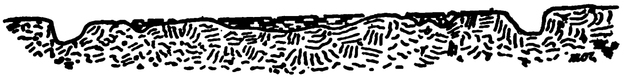
On sidehill roads it is sometimes suggested that instead of the center being crowned, the surface be made to slope toward the inner bank, so that all water may flow into the ditch there, instead of being allowed to run over the face of the embankment. This is bad practice, however, except on sharp curves, as more water is on the road, and for a longer period than when the slope is from the center toward the sides. To protect sidehill roads from the drainage from above, additional ditches should be placed higher up to intercept water flowing toward them.

It is clear that unless a dirt road receives constant attention to preserve the crown and the smoothness of the surface, the drainage will have to depend upon the grade rather than upon the crown, for, as the material is soft, the latter is soon destroyed. To correct this tendency, therefore, all depressions should be immediately filled with good fresh earth, while the surface should be constantly smoothed or rounded off.

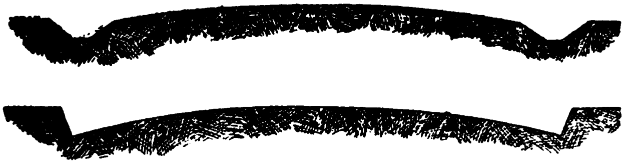
Subsurface drainage means the draining of the soil, beneath the covering, of water which may have gotten into it either from above or from the subsoil below. This is the best method of caring for a road, as it drains the soil of the ground water, precludes mud and prevents frost action. A road built upon a wet and undrained base will be expensive to maintain if it is not altogether destroyed by the action of water and frost. Ground water is a very important factor, and particularly in excavation, where it tends to flow toward the road; in embankment, on the other hand, the water tends to flow away from the road.

It seldom happens that dirt roads need be underdrained for any distance, but it frequently does occur that at some particular point it is necessary to collect the water in the bed of the road, or to carry it from one side to the other by this means.

Under such circumstances the method adopted depends in a measure upon the nature of the soil. Porous tile drains of burnt clay seem to collect and dispose of the water most satisfactorily, as they neither become choked nor require much grade. Such tiles are made in various forms and size, but those of circular cross section three or more inches in diameter, are to be preferred.

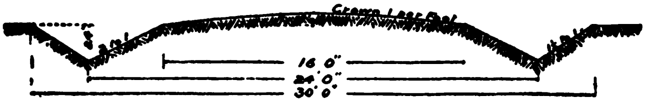


IMPROPERLY CONSTRUCTED 14-FT. ROAD—POOL OF WATER AT CENTER

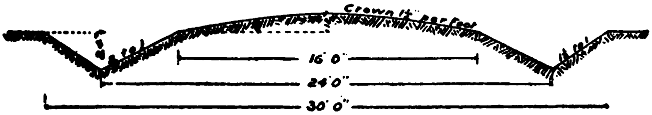


TWO EXAMPLES OF PROPERLY CROWNED ROADS—THE LOWER MAY BE MADE WITH A ROAD MACHINE

LOOSE, UNROLLED ROAD AT LEFT AND COMPACT, ROLLED ROAD AT RIGHT

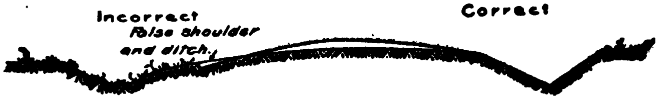


PROPER SECTION FOR LOAMY SOIL

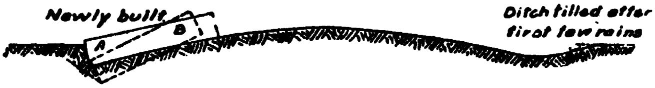


PROPER SECTION FOR CLAYEY SOIL

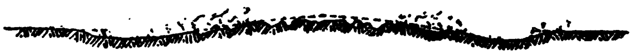
EXAMPLES OF PROPER AND IMPROPER EARTH ROAD CROSS SECTIONS



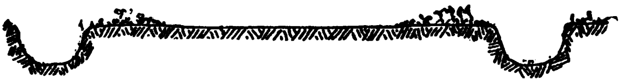
COMMON MISTAKE SHOWN AT LEFT—CORRECT FORM AT RIGHT



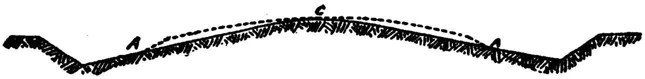
PITCH AS COMMONLY LEFT BY GRADER; BLADE IN POSITION "A"—CORRECT LAST CUT IN POSITION "B"



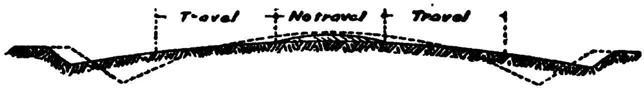
RESULT OF NEGLECT—ORIGINAL SURFACE SHOWN BY DOTTED LINE



INCORRECT FORM OFTEN SEEN—FLAT ROAD



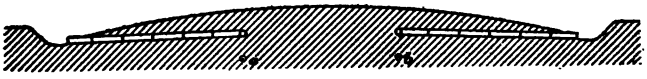
ROAD WITH TOO MUCH CROWN—CORRECT SECTION SHOWN BY DOTTED LINES



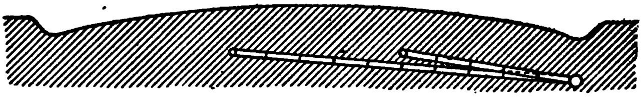
ROAD GRADED TOO WIDE AND FLAT—CORRECT SECTION SHOWN BY DOTTED LINE

EXAMPLES OF PROPER AND IMPROPER EARTH ROAD CROSS SECTIONS

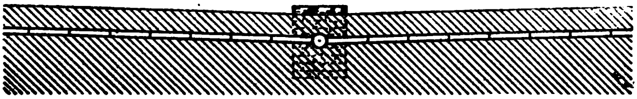
Drains may be placed in a number of ways along the road, as, for example, a single line beneath the center of the roadbed; a single line under one of the side ditches; two lines, one beneath each of the side ditches; or by laying the drains herringbone fashion along the middle of the road with the points directed up-hill, 15 to 30 ft. apart and the branches falling away to the side ditches into which they discharge. In any case, they should be at a depth of two or three feet below the frost line, to keep the subgrade well drained and prevent the pressure of heavy loads from breaking them.



TRANSVERSE DRAINS LEADING TO SIDE DITCHES—IF LOWER OUTLETS CAN BE SECURED LONGITUDINAL DRAINS MAY BE PLACED AT "A" AND "B"



LEVEL ROAD WITH DRAINS TO LARGER PIPE AT SIDE



LONGITUDINAL ROAD SECTION SHOWING DRAINS DISCHARGING TO CULVERT PIPE

THREE EXAMPLES OF UNDERDRAINING ROADS WITH TILE

To prevent small animals from entering the drains and choking them up, the outlets should be protected with wire netting placed over the mouth, and to avoid the possibility of the water scouring the banks, the ends should project some distance beyond and be set in some sort of masonry.

The method of laying the tile with small stone directly above and earth over this is common practice. The ends of each length are placed in close contact with the two adjoining ones, and no collars are necessary to prevent silt from entering at the joints.

The size of such drains depends on the estimated amount of water to be carried off and the grade, but should never be smaller than 3 or 4 ins. A grade of 1 to 60, or 1 in. in 5 ft. will be found sufficient to care for the water, though as low as ½ in. per 100 ft. has been used successfully in flat countries. Where the ground is practically level, grade may be secured by placing the upper end of the pipe line nearer the surface than the outlet end.

The following table shows the size of pipe required with a given grade to discharge a given quantity of water:

SIZES OF DRAIN-PIPE REQUIRED IN PROPORTION TO CAPACITY AND FALL.

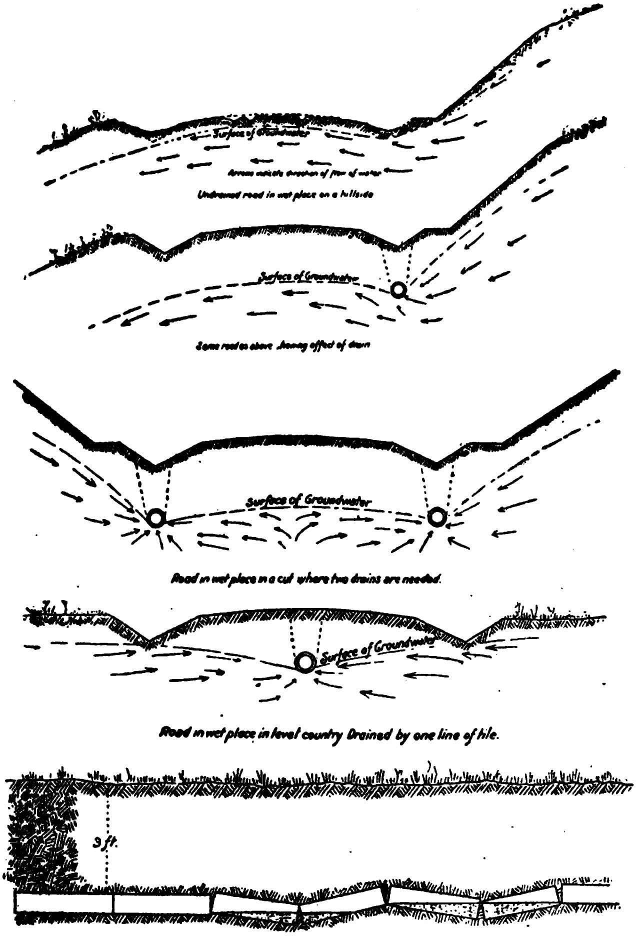
Ins.	3-in. Fall per 100 ft. Gals. per Min.	6-in Fall per 100 ft. Gals. per Min.	9-in. Fall per 100 ft. Gals. per Min.
6..........	129	183	224
8..........	265	375	460
9..........	355	503	617
10..........	463	655	803
12..........	730	1,083	1,273
15..........	1,282	1,818	2,224
18..........	2,022	2,860	3,508
24..........	4,152	5,871	7,202

Where water is to be carried beneath the roadway from one side to the other in large quantities, a culvert may have to be built. Culverts should be protected at the ends where they come out of the embankment in the same manner as drains, only to a greater degree, by wing walls and an apron of masonry to prevent scouring, and for this reason it is better to have a stone foundation for the culvert than one of earth.

For a satisfactory and cheap method of road drainage there is none better than that afforded by the side ditches, and most frequently this is the only one employed to any extent, or the only one found necessary. These ditches are placed on both sides of the roadway wherever possible, not only to carry off the water falling on the surface of the road and draining into them, but to intercept that which may flow from neighboring land toward the highway. They further perform the service, when deep enough, of draining the subgrade.

Where open ditches may not be conveniently used at the sides, other forms are employed to do the same work.

All open ditches should be of such a cross section that a



Undrained road in wet place on a hillside

Same road as above showing effect of drain

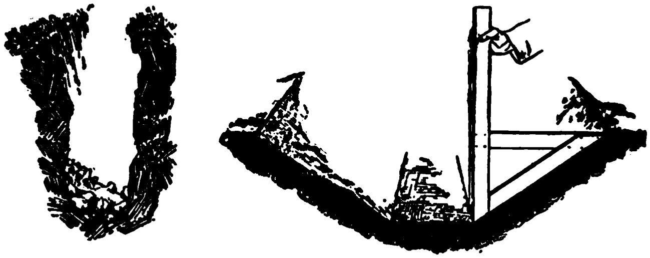
Road in wet place in a cut where two drains are needed.

Road in wet place in level country Drained by one line of tile.

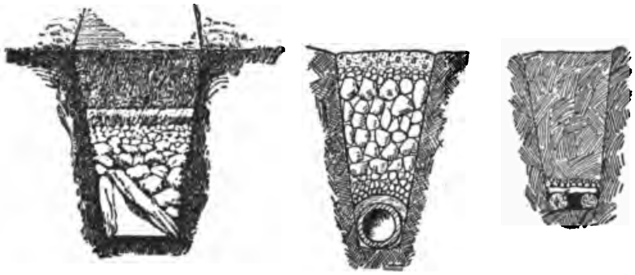
Tile drain showing irregular settling as a result of laying in soft soil. The opening is nearly filled by silt where the joints are lowered. A plank under this would have held the tile in alignment and should have been used when they were laid.

SKETCHES SHOWING SOME OF THE PRINCIPLES
OF DRAINAGE

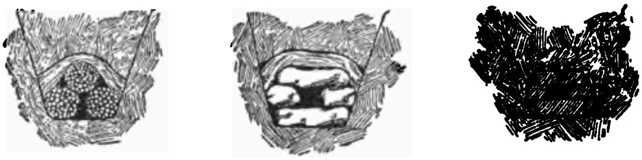
scraper or road machine may be easily used in their formation and maintenance, as they are then easier and cheaper to keep in repair. The shallow ditch is, all things considered, much



DITCH DUG BY EROSION, AT LEFT—PROPER FORM OF DITCH, AND METHOD OF BUILDING, AT RIGHT



SUBDRAINS BUILT WITH FIELD STONE, FIELD STONE AND TILE AND LOGS AND WOOD FAGOTS



SUBDRAINS FOR CARRYING SPRING WATER UNDER OR ALONG ROADS— BUILT WITH BRUSH, FIELD STONE AND BRICK

SKETCHES OF DITCHES AND SUBDRAINS OF VARIOUS KINDS

the more preferable, not only because, from the standpoint of cost of construction and maintenance and repair, it is cheaper, but because it also affords an easy and safe place to turn out when teams are crowded to the side. It should be remembered, on the other hand, that the deeper a ditch is, the better the subgrade will be drained. Side ditches should be kept entirely free from foreign material, such as brush, sticks, stones, weeds, etc., since its presence prevents the speedy discharge of the water gathered there. This discharge can be secured only by a grade sufficient to carry off the water and any suspended matter it may contain, yet, it should not be so great as to cause washing of the side banks.

It is needless to say that side ditches should never so far fail as to permit water to stand in them for any length of time, for this simply keeps the subgrade soft and moist, and it should be corrected by either a change of grade or the cleaning out of the ditch and its outlet.

On steep grades it is well to have the ditches so far removed from the road that a strip of brush or small trees may be grown between them and the highway to afford protection to the side slope next the road, by means of the roots, and thus prevent the scouring action of the water with the final destruction of the road. Much more frequently the same result is accomplished by sodding the side slopes or laying field stone in the gutters. A slope of 1 in 100 will give satisfactory results for this sort of drainage, but often this value must necessarily be greatly exceeded because of the grade in the road itself. Where such is the case, the erosion in the ditch may then be considerable unless some provision as noted above is made.

The transverse contour or crown may be in the form of a gentle curve with the highest point at the center, or of two planes intersecting at the middle of the road, but in dirt roads this makes little difference. With smooth, hard pavements, the crown may be made small; but in dirt roads, the maximum must be applied, with judgment, however, for too much of it does not keep the surface as dry as a flatter one. For satisfactory surface drainage and yet not too excessive crown, a rise of 1 in. in 12 ins. is recommended as a maximum for dirt roads.

WIDTH OF ROADS

The right of way, which means the space between fence lines, varies in the United States from 40 to 100 ft. In dirt roads it is always well to use as much of this as is consistent, not only to prevent the effect of traffic following the same line, but to secure the advantages of sun and wind which

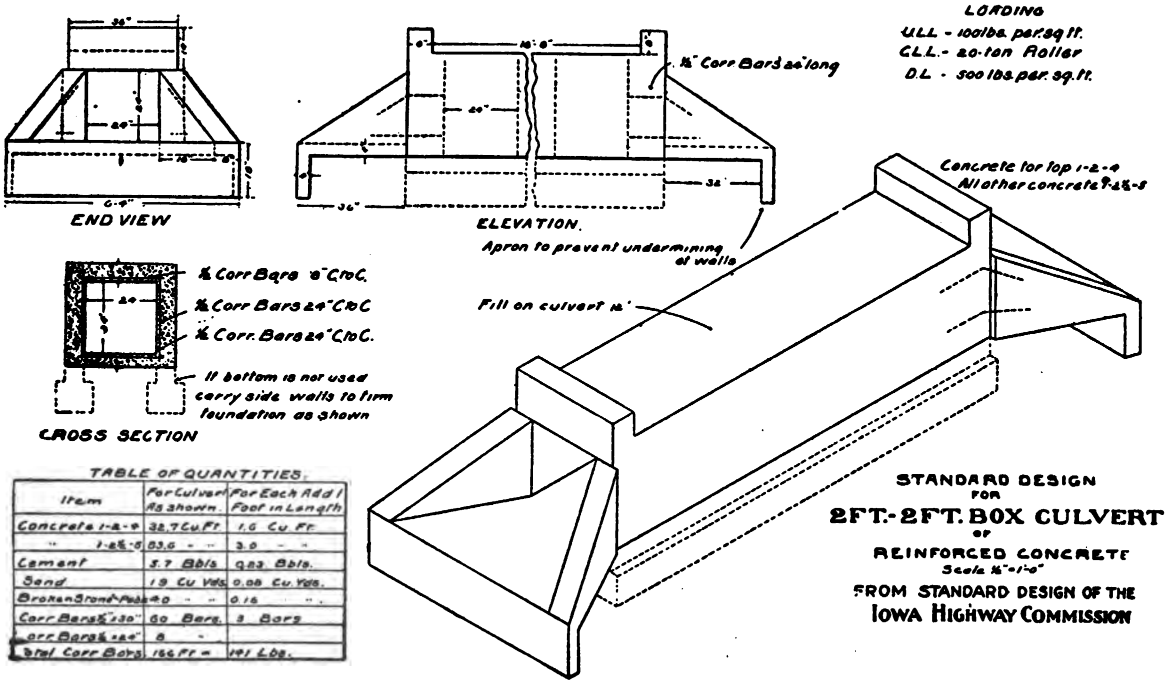


TABLE OF QUANTITIES.

Item	For Culvert As shown.	For Each Add'l Foot in Length
Concrete 1-2-4	32.7 Cu. Ft.	1.6 Cu. Ft.
" 1-2½-5	83.6 " "	3.0 " "
Cement	5.7 Bbls	0.23 Bbls.
Sand	1.9 Cu Yds.	0.08 Cu. Yds.
Broken Stone or Pebbles	4.0 " "	0.16 "
Corr Bars ⅜"×30"	60 Bars.	3 Bars
Corr Bars ⅜"×24"	8 "	
Total Corr Bars	166 Ft =	141 Lbs.

STANDARD DESIGN
FOR
2 FT.-2 FT. BOX CULVERT
OF
REINFORCED CONCRETE
Scale ⅛"=1'-0"
FROM STANDARD DESIGN OF THE
IOWA HIGHWAY COMMISSION

are the most important natural factors for keeping the roadway dry. Particularly in wet weather are wide roads advantageous, as they permit a choice of route. On the other hand, any increase in the width means an increase in the cost of construction and in the item of maintenance and repair.

Frequently in small towns where dirt roads are extensively used, the width of wheelway, 40 to 45 ft., is far greater than the demands of traffic require, or is desirable from an economical standpoint. A much better arrangement is a narrow wheelway with the rest of the space devoted to grass plots, whereby the cost of repairs is reduced and the appearance of the street improved. On purely rural highways, where the traffic is light, the width of traveled way will be about 12 ft. as a minimum, but such roads are always provided with shoulders that make it possible for teams to turn out in passing each other.

SIDE SLOPES

The slope of the banks, to both the ditches and the sides of the roadbed, either in excavation or in embankment, depends primarily upon the nature of the material. Where this is firm and will stand, as with rocks, as small a slope as that represented by a vertical rise of 4 ft. in 1 ft. horizontal may be sufficient; but where it is soft or yielding, as in sand, a slope of 1 ft. vertical to 4 ft. horizontal may be required. In the latter case the grade will also have to be small to prevent the transportation of material, unless some method of protecting the ditches is adopted.

The most common slope is 1 on 1½ or a rise of 1 ft. in a distance of 1½ ft. since at that angle most earth embankment will stand. It is always better to have the side slopes as gentle as possible, as the broader the ditch the less likelihood there is of the material slipping when water-soaked.

EARTHWORK

The term earthwork, which is applied to all operations of embankment or excavation, in the preparation of the roadbed, includes both rock and earth. The excavation should always be in such amount, within reasonable limits of haul, as to equal the embankment for where this condition does not exist, material in the one case must be borrowed from off the right of way to satisfy the "fill," while in the other it becomes necessary to waste the excess of "cut." In the former case the material is taken from a borrow pit, while in the latter the place where it is wasted is called a spoil bank. In balancing "cut" and "fill" it is very necessary to remember that different materials occupy greater or less space after excavation than before; thus the amount of shrinkage after displacement, is shown by the figures below:

Gravel	8 per cent.
Gravel and sand	9 per cent.
Clay and clay earths	10 per cent.
Loam and light sandy earths	12 per cent.
Loose vegetable soil	15 per cent.
Puddled clay	25 per cent.

On the other hand, rock increases in bulk by about 50 per cent.

MAINTENANCE

A typical country road is usually maintained and kept in repair by the aid of labor which is more or less ignorant of the fundamental principles underlying such work, or not interested in the results. Furthermore, the work is undertaken perhaps once or twice a year, and the havoc created then is supposed to keep the road in condition the rest of the time. This method is absolutely at odds with the needs, for a dirt road, above all others, is one that is readily broken up, and that requires constant and careful attention to keep it in a satisfactory state. Generally speaking, for the best results the system of continuous small repairs should be employed. Applied to dirt roads, it means the daily or periodic inspection of the section in question, the removal of all stones, etc., from the highway, the filling up of ruts, depressions, and holes, the careful attention to drainage, surface, crown, etc., the removal of brush, weeds, sod, sticks, and stones from side ditches, the cleaning out of the same and of all drains or culverts to permit the free flow of water, together with the removal of snow in winter, and perhaps the application of oil in summer.

One of the worst features of the present day practice of earth road maintenance is that instead of removing a thin surface layer of material that is valueless, having lost all of its binding properties, there is added to it more of the same character from the side ditches. The consequence is that this material is soon converted into dust or mud again, and deposited in the side ditches from which it came, with the loss of the crown and the filling up of the ditch as the resultant twofold disadvantage. Any material lacking in binding power should be removed from the roadway to such a distance that there would be no possibility of its getting back again.

DRAGGING

Of all methods known to highway engineers for the purpose of maintaining earth roads in good condition, there is none, aside from drainage, that can compare with, or deserves more attention than, the road drag.

Road dragging is the simplest, most effective and inexpensive method for the improvement of earth roads that is known. In many cases it is found that where the road is dragged it is unnecessary to supplement it by underdrainage, but the most important thing is that the road drag will leave a smooth, hard surface, if properly used. If, however, during the winter, certain parts of the road break through, it will indicate improper drainage and tile drains should be employed to remedy the defect.

The exact form of drag is unimportant, as nearly any device should prove effective which will move a small amount of material toward the center of the road, and at the same time smooth over the surface. In view of the fact that effective dragging depends upon this feature, no drag should be of heavy design, but on the contrary, the lighter and simpler the construction the better.

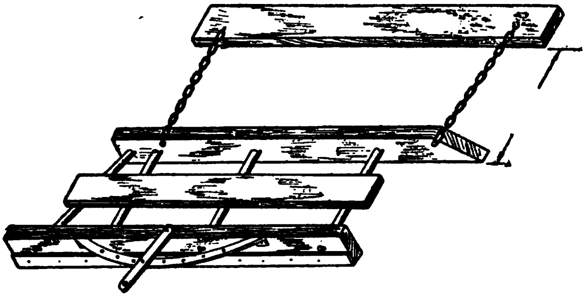
While a stick of timber or piece of railway rail may often prove satisfactory, V-shaped drags, probably because of excessive weight, will not always give good results. Perhaps the cheapest and simplest form of all is that known as the "split log drag."

The figure shows a cut of such a drag, in which the log is 9 ft. long and between 10 and 12 ins. in diameter. The holes in the front half are inclined so that the lower part of the face receives a slight slant forward, while the holes in the rear half are bored so that the face will stand perpendicularly to the braces. These latter are made to taper in order to fit snugly in the holes and join the two together. The holes should not be less than 2 ins. in diameter, and the ends of the cross braces fitting into them should be split, so that the wedge which is inserted, may bind them more securely in place. These wedges are driven into the braces across the grain of the log or plank to prevent splitting of the latter, and a diagonal brace is placed between the logs at the leading end to stiffen the frame. The distance between the faces of the logs should be about 3 ft. with the lower edge of the front one protected by a strip of iron about ¼ in. thick, 3 or 4 ins. wide, and not more than

4 ft. long, bolted to it and with the heads of the bolts countersunk, to prevent obstruction.

Chains for hauling the drag are arranged with a short and long hitch so that it may travel at an angle of 45 degrees with the axis of the road. The long hitch of the chain should go over the log around one of the cross pieces rather than through a hole in the forward log, to permit of the earth sliding free along the front face.

Some forms of drag are made of planks reinforced on the inner side by 6-in. pieces, and they have the slight advantage that the earth moves more freely along the face than in the previous type.



HOME MADE ROAD DRAG OR HONE

With a platform of one-inch plank laid on the cross pieces for the driver to stand on, the entire cost of a drag is found to be not over $3.00 or $4.00.

While such drags as described may be made by almost anyone, more durable and probably more efficient drags, made wholly or partly of metal, may be purchased for comparatively little. There are many of these on the market, all more or less alike in general construction, but varying in details.

The objects of the road drag are to smooth the surface of the road when soft and muddy and at the same time move a small amount of moist earth toward the center and thereby maintain the crown. It is not intended for the purpose of moving large quantities of earth, nor does the maintenance of a dirt road ever require this.

The theory depends upon the following facts: If a sample of moist earth is taken from the traveled portion of a road in a gumbo, clay, or black prairie soil, it will be found practically impervious to water. Earth in this condition is what clay workers call "puddled" and is produced in a sticky, muddy road from having been worked and reworked by carriage wheels and animals' hoofs until nearly all the traveled portion is covered with a layer of this material. As usually found on dirt roads, this puddled earth is full of holes and ruts filled with water which cannot escape through the impervious soil. As long as the water remains, the surface cannot dry out and the road is kept in a poor condition. It is true, however, that this puddled earth when compressed and dried becomes extremely hard. On these two facts—the imperviousness of puddled earth and its hardness when dried—rests the theory of road dragging.

When the drag is properly used it spreads a layer of impervious soil over the road and fills up the ruts and hollows until a smooth surface is secured. As a small amount of material is always pushed to the center, a slightly rounded effect will result which may be increased or decreased by subsequent treatment. By forcing the mud into the low places the water is expelled and made to run off to the side, thus facilitating the drying out process, and immediately making the surface firmer.

The effect of traffic is to thoroughly compact the top, and each thin layer of puddled earth which the drag spreads over the surface is later subjected to this action. As a result, after the first few draggings it is found that the surface becomes constantly smoother and harder and little rain remains on the roadway, as the water runs off of the smooth hard surface with practically no absorption.

The following are the points to be borne in mind in dragging a road:

1. Make a light drag, and haul it over the road at an angle so that only a small amount of earth is pushed to the center of the road.
2. Drive the team at a walk and ride on the drag; do not walk alongside.
3. Begin on one side of the road and return on the opposite side.
4. Drag the road as soon after every rain as possible, but not when the mud is in such condition as to stick to the drag.

Do not drag a dry road. Unless the road is in the right condition the work of dragging is wasted. The right time is when the road is wet, the muddier the better.

On a very muddy and bad road the lap-plank drag is best. It is better to drag in dry seasons when the rain is actually falling, as otherwise the roadbed absorbs the rain before the drag is put into use and the mud or earth is simply worked over the road as a mortar.

Don't drag a dry road, as it merely crumbles up the surface and makes a layer of loose material which is soon converted into mud which will hold water on the surface of the road—exactly the condition to be prevented.

5. Drag whenever possible at all seasons of the year. A road dragged immediately before a cold spell will freeze in a smooth condition.

6. The width of traveled way to be maintained by dragging should be from 18 to 20 ft.; first, drag a little more than the width of a single wheel track, then gradually increase until the desired width is obtained. When a width of 20 ft. is to be dragged at least two round trips should be made.

7. Always drag a little earth toward the center of the road until it is raised from 10 to 12 ins. above the edges of traveled way. If the drag cuts in too much, shorten the hitch.

8. The amount of earth that the drag will carry along can be controlled more or less by the driver, depending upon whether he stands near the cutting end or away from it.

9. When roads are first dragged after a very muddy spell, wagons should drive, if possible, to one side until the highway has a chance to freeze or partially dry out.

10. The best results from dragging are obtained only by repeated applications. Constant attention is necessary in order to maintain an earth road in its best condition.

Roads properly dragged, dry out weeks earlier in the spring than others, and when dry are smooth and firm, besides which they do not rut so readily.

An ordinary country road may thus be well maintained by dragging twice a month, with more frequent draggings during the winter and spring and less during the summer.

SAND-CLAY AND BURNT CLAY ROADS.

Sand-clay and burnt clay roads, which we may consider as modifications of ordinary dirt highways, have received considerable attention from road engineers, particularly in the South, in the Gulf and Atlantic States and in the valley of the Mississippi or those rivers draining into it, where road building materials are not to be had except at excessive cost.

In some of these localities both sand and clay are to be found in considerable quantities, but only recently have they been made use of, combined with each other, in the construction of improved roads, which, experience seems to show, give very satisfactory results for the money expended upon them.

SAND-CLAY ROADS

Sand-clay roads naturally separate themselves into two general classes, if we take as the distinguishing characteristic the nature of the subsoil; that is, whether the roadbed is of sand or whether it is of clay.

We shall consider the road with a sandy base first, as it is the simpler proposition, for where sand or a sandy soil is found, drainage is always good, the water sinking below the surface without any assistance by artificial means. But because of its loose character, sand makes a very poor road material, permitting horses' hoofs and wagon wheels to sink so deep into it that the effort to haul a load is considerably increased and in a corresponding degree the load itself is decreased.

It is well known that if sand be confined within a given space, so that it cannot spread or run, it forms a most excellent material for foundation work and will carry the heaviest of loads. This is just the function which the clay has to perform when it is mixed with the sand, for it cements each grain of sand to all its neighbors, and thus keeps the sand in place, so that it cannot spread or scatter.

The theory on which the mixing of these two materials depends is absolutely that which applies in the mixing of mortar, the idea being to have good sharp particles of sand, so that there will be a natural mechanical bond existing between them, such as is never present with rounded grains, which slip and slide over each other, together with some good binding, or cementing material which shall be in sufficient quantity to cover each grain with a thin layer, and at the same time fill all the voids between the different grains, but no more. This the clay does.

If there is not enough clay the sand grains fall apart, and the road surface breaks up, while if there is too much the wheels of traffic sink into the clay and a heavy, sticky road results in wet weather.

In the case of the road where the material of the subgrade is sand, it is not so necessary to consider the matter of drainage, since the natural porous or open condition of the soil provides for it; nevertheless, to keep water away from the road is, as in all cases of highway construction, the most important part of the entire work since water and clay make mud, and this is the element we most desire to dispense with. In addition to this, as soon as the clay binding the grains of sand together is softened the surface becomes disintegrated.

Where wet spots occur in a sand road, if they can be kept permanently wet, it will be unnecessary to add clay, as the water and sand are better than water and sand and clay, the water acting with the sand alone as a sort of binder. Witness, for example, the hard condition of a sandy beach where the water is intermittently washing over it and keeping it wet, so that in fact it will sustain the heaviest traffic, while a few paces back where it is dry, the sand is so loose as to be easily drifted by the wind. In case the water is not continuously present, then means should be taken to thoroughly drain that portion of the road so that it will be absolutely dry at all times, whereupon clay may be mixed with the sand, and treated as the rest of the road.

The method adopted in constructing roads where sand is the base and clay is to be added as a top dressing, consists in crowning the old roadbed, as well as conditions will permit, and thoroughly preparing it for the reception of the clay. On this prepared surface there should then be spread, beginning at a point nearest to the supply, a covering of clay, and it may be noted that this material should be in as small pieces as possible so that it will more intimately mix and combine with the sand. Huge chunks must be avoided, as satisfactory results cannot be expected where large pieces are applied. Six or eight inches of this clay will be sufficient. After the placing of it, the two materials should be thoroughly mixed by turning them over with a plow or harrow or both. The clay should be deepest at the center, thinning out to the sides. The best time to do this mixing is immediately after a rain when the clay is soft and pasty, and will readily combine with the sand. Where conditions are right the plow and harrow may be dispensed with, the work being left to the action of traffic, but the results can hardly be so good, nor will they be secured in as short a period of time as if the plow and harrow were employed.

In general this work requires time for the complete benefits to be apparent, and it cannot be expected that the road will be satisfactory if no further attention is given to it after the time of placing the clay upon it. It may be that too little or too much clay has been added, and this of course can be determined only by careful observation of the road under traffic for some time after the improvement has been made. If too much clay is present it will be sticky in wet weather, and if too little, it will break up in dry. The correction is obvious. A road machine to crown and smooth the surface is of material assistance in shaping the road to the desired cross section and having it dry out that way.

The road with a base of clay is a much more difficult proposition to handle, as here the drainage of the roadbed plays a most important part. With this fact in mind, and again remembering that water and clay together make mud—which is to be avoided—side ditches should be constructed with a road machine the entire length of the improvement with the bottom of the ditch not less than 18 ins. below the crown of the road at the center. This provision will keep all ground water that may be in the soil from reaching the roadbed, and thereby prevent the softening of the material. If the crown likewise is carefully attended to, and given a fall of not less than ½ in. per foot from the center to the sides, all rain falling on the surface will be immediately diverted to the side ditches.

The old roadbed should therefore be shaped as recommended above, after which it should be plowed up to a depth of about 4 ins., so that when the sand is spread over the surface it will mix freely with the clay. This sand should be laid to a depth of from 6 to 8 ins. over the roadway with the greatest depth at the center. It should then be well harrowed so as to make the mixing complete and after the first hard rain treated in the same manner, so as to puddle it. If there is an excess of clay it will work to the top and can, of course, be taken up with more sand.

After the final puddling the road should be shaped with a road machine or roller, while wet, so it will dry out hard and with the desired crown.

These roads, like the previous ones, need some attention after the final shaping until they have gotten their permanent form.

It is impossible to give exact rules covering the construction of these roads as experience and intelligence in handling the material at hand are such important factors. The reason for this is that the percentage of voids in sand is a decidedly varying quantity, making the amount of clay to be used to fill these voids a varying quantity also, besides which the clays themselves vary. It will be found that some of them are extremely sticky and, therefore, possess good binding qualities, while others disintegrate with the absorption of water. This is a highly desirable quality also, within limits, for it guarantees the breaking up of the clay without mechanical means and the consequent intimate mixture of the sand with it. The ideal clay, therefore, is one that possesses a maximum binding power, with a sufficient tendency to disintegrate to guarantee its breaking into comparatively small pieces, and thus save the labor otherwise needed to accomplish this.

That these roads are deserving of careful consideration and study is self-evident, for the localities in which the materials are found cover a large area of the country, and in the rural highways at least, no other material can be economically employed. They have the advantage of costing little to construct and to maintain and repair, in fact less than any except it be the dirt road itself, and give infinitely better service.

BURNT CLAY ROADS

Burnt clay roads are in a sense only a modification of those mentioned above, though the treatment in their preparation is essentially different. In considerable portions of the South, particularly in the valleys of the Mississippi and those rivers flowing into it, where the low-lying adjacent land has been formed from the silt carried by the rivers at the high seasons and deposited there when they overflow their banks, the material of which the roads are built is locally known as buckshot or gumbo. This possesses the extremely undesirable quality of becoming very sticky in wet weather, and at certain seasons of the year renders the roads of which it is made positively impassable.

To remedy this, after some experimentation, the U. S. Office of Public Roads hit on the plan of burning the material, which clinkers at a low temperature, and thus through the agency of heat converting the soft clay into a hard material.

The method adopted by the Office of Public Roads which gave most satisfactory results, was in brief as follows: The road was first graded to the width it was to have finally, and then plowed up as deeply as possible. Cross furrows, 4 ft. apart, were run across the road from ditch to ditch, which extended about 2 ft. beyond the surface to be burned. The material dug up from these cross furrows served as ridges on which to place cord word which was to do duty in the firing.

The first layer of this wood was placed along the direction of the road with the pieces as close together as possible to form a sort of platform. The next layer of cord wood was placed at right angles across this with spaces between the logs so that chunks and pieces of clay could be placed between. The third layer of wood was placed as the first, and the fourth as the second, and so on, until enough layers had been built up to guarantee sufficient burnt clay to form a hard surfacing. Over the entire construction was placed clay to a depth of 6 ins. in large and small pieces which were tamped so as to insure no cracks or crevices and to insure a good draught.

The result of such procedure is that the material in the piles and the material on which the wood rests is thoroughly burned and clinkered. The road is then highly crowned and rolled until hard and smooth.

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The past decade has witnessed notable changes in the construction, repair and maintenance of country roads and city streets. A great industry has grown up and today more than $150,000,000 is annually expended in this work.

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